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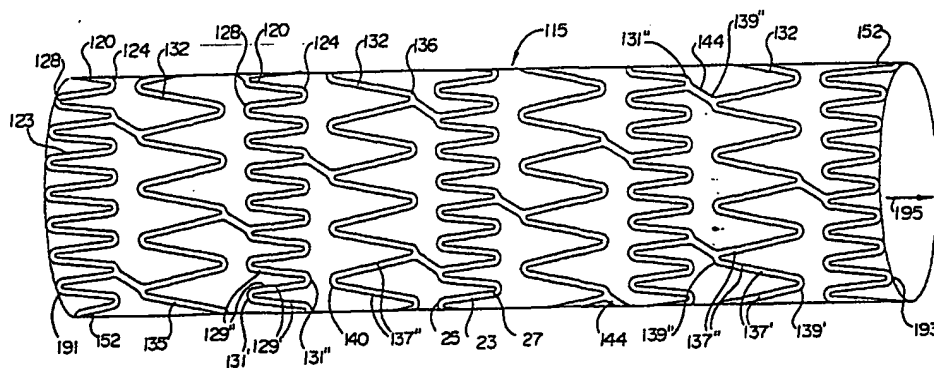


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(54) Title: LONGITUDINALLY FLEXIBLE EXPANDABLE STENT



(57) Abstract

Segmented articulatable stent of open structure comprised of end-connected struts of first and second lengths making up first and second segments with angular interconnects between adjacent first and second segments.

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## AMENDED CLAIMS

[received by the International Bureau on 23 May 2000 (23.05.00);  
original claims 1-37 replaced by new claims 1-36 (5 pages)]

1. A stent having a proximal end and a distal end comprising:  
a plurality of connected undulating band-like elements, the band-like elements having alternating peaks and troughs aligned on a common longitudinal axis to define a  
5 generally tubular stent body, the band-like elements including first and second band-like elements, the first band-like elements having a first selected wavelength, the second band-like elements having a second selected wavelength, the second selected wavelength different from the first selected wavelength,  
wherein at least some of the peaks on each band-like element are connected to  
10 some of the troughs on an adjacent band-like element.
2. The stent of claim 1 further comprising interconnecting elements, each interconnecting element having a first end and a second end, the first end circumferentially and longitudinally offset from the second end,  
wherein at least some of the peaks on each band-like element are connected via  
15 the interconnecting elements to some of the troughs on an adjacent band-like element.
3. A stent having a proximal end and a distal end comprising:  
a plurality of interconnected undulating band-like elements, the band-like elements having alternating peaks and troughs, aligned on a common longitudinal axis to define a generally tubular stent body,  
20 the undulating band-like elements interconnected by a plurality of interconnecting elements, each interconnecting element having a first end and a second end, the first end extending proximally from a band-like element and the second end extending distally from an adjacent band-like element, the first and second ends offset circumferentially and longitudinally along the stent wherein each of the interconnecting elements comprises a  
25 first shank, a second shank and a link disposed in-between the first and second shanks, the first shank extending in a longitudinal direction from a peak, the link extending substantially perpendicular from the first shank and the second shank extending in a longitudinal direction from a trough and perpendicular to the link.
4. A stent having a proximal end and a distal end comprising:  
30 a plurality of interconnected undulating band-like elements, the band-like elements having alternating peaks and troughs, aligned on a common longitudinal axis to

define a generally tubular stent body,

the undulating band-like elements interconnected by a plurality of interconnecting elements, each interconnecting element having a first end and a second end, the first end extending from a band-like element and the second end extending from an adjacent band-like element, the first and second ends offset circumferentially and longitudinally along the stent wherein each of the interconnecting elements is curvilinear.

5     The stent of claim 4 wherein the curvilinear element extends in a direction substantially oblique to the longitudinal axis of the stent.

6.     The stent of claims 3, 4 or 5 wherein adjacent band-like elements are 180° out of phase with one another.

7.     The stent of claims 3, 4 or 5 comprising interconnecting elements which extend from peaks on a band-like element to second nearest neighboring troughs on adjacent band-like elements.

8.     The stent of claims 3, 4 or 5 wherein adjacent band-like elements are less than 15   180° out of phase with one another.

9.     A stent having a proximal end and a distal end comprising:

a plurality of interconnected undulating band-like elements comprised of connected struts, the band-like elements having alternating peaks and troughs, aligned on a common longitudinal axis to define a generally tubular stent body, the band-like elements comprising first struts of a first length and second struts of a second length different from the first length;

the undulating band-like elements interconnected by a plurality of interconnecting elements, each interconnecting element having a first end and a second end, the first end extending from a band-like element and the second end extending from an adjacent band-like element, the first and second ends offset circumferentially and longitudinally along the stent.

10.    The stent of claim 9 wherein the interconnecting elements are linear.

11.    The stent of claims 9 or 10 including first band-like elements consisting of first struts and second band-like elements consisting of second struts.

12.    The stent of claim 9 or 10 wherein each band-like element is formed of first and second struts.

13. The stent of claim 12 wherein each band-like element further comprises third struts of a third length different from the first and second lengths.
14. A stent having a proximal end and a distal end comprising:  
a plurality of interconnected undulating band-like elements, the band-like  
5 elements having alternating peaks and troughs, aligned on a common longitudinal axis to define a generally tubular stent body,  
adjacent undulating band-like elements interconnected by first interconnecting elements of a first length second and second interconnecting elements of a second length, the first length different from the second length.
- 10 15. The stent of claim 14 wherein the first interconnecting elements extend from peaks on undulating band-like elements to troughs on adjacent band-like elements and the second interconnecting elements extend from peaks on undulating band-like elements to troughs on adjacent band-like elements.
16. The stent of claims 14 or 15 wherein the first and second interconnecting  
15 elements are linear.
17. The stent of any of claims 14-16 wherein at least some of the undulating band-like elements comprise a first segment characterized by a first wavelength and a second segment of a second wavelength different from the first wavelength.
18. The stent of any of claims 14-17 wherein the first interconnecting elements are  
20 disposed at a first oblique angle relative to the longitudinal axis and the second interconnecting elements are disposed at a second oblique angle relative to the longitudinal axis, the second oblique angle differing from the first oblique angle.
19. The stent of any of claims 1-3 and 11 wherein the first and second band-like elements alternate along the length of the stent.
- 25 20. A stent having a proximal end and a distal end comprising:  
a plurality of interconnected undulating band-like elements, the band-like  
elements having alternating peaks and troughs, aligned on a common longitudinal axis to define a generally tubular stent body,  
the undulating band-like elements interconnected by a plurality of interconnecting  
30 elements, each interconnecting element having a first end and a second end, the first end extending from a band-like element and the second end extending from an adjacent band-

like element, the first and second ends offset circumferentially and longitudinally along the stent wherein each of the interconnecting elements consists of a first shank, a second shank and a link disposed in-between the first and second shanks, the first shank extending in a circumferential direction from the side of the peak, the link extending  
5 longitudinally and the second shank extending in a circumferential direction from the side of the trough.

21. The stent of any of claims 2-20 comprising interconnecting elements extending from peaks of band-like elements to troughs of adjacent band-like elements wherein interconnecting elements extending from peaks of a band-like element are separated from  
10 interconnecting elements extending from troughs of the band-like element by at least one unconnected peak having no interconnecting elements extending therefrom and at least one unconnected trough having no interconnecting elements extending therefrom.

22. A stent comprising:

a plurality of connected undulating band-like elements, the band-like elements  
15 having alternating peaks and troughs aligned on a common longitudinal axis to define a generally tubular stent body,

a plurality of interconnecting elements, each interconnecting element having a first end and a second end, the first end extending from a band-like element, the second end extending from an adjacent band-like element, the first and second ends displaced  
20 circumferentially along the stent,

wherein at least some adjacent peaks in a band-like element are longitudinally offset from one another.

23. The stent of claim 22 wherein at least some adjacent troughs in a band-like element are longitudinally offset from one another.

25 24. The stent of any of claims 22 and 23 wherein the interconnecting elements extend from peaks on a band-like element to troughs on an adjacent band-like element.

25. The stent of any of claims 22-24 comprising interconnecting elements of a plurality of different lengths.

26. The stent of any of claims 22-25 wherein adjacent band-like elements are  
30 interconnected by interconnecting elements of more than one length.

27. The stent of any of claims 22-26 comprising band-like elements whose

wavelength varies along the band-like element.

28. The stent of any of claims 22-27 comprising band-like elements whose amplitude varies along the band-like element.
29. The stent of any of the previous claims formed of a metal.
- 5 30. The stent of claim 29 wherein the metal is a shape memory alloy.
31. The stent of any of the previous claims wherein the stent is a thin-walled tubular member.
32. The stent of any of the previous claims in a self-expanding configuration.
33. The stent of any of the previous claims in a mechanically expandable
- 10 configuration.
34. The stent of any of claims 4, 9, 14 or 22 wherein the interconnecting elements extend from peaks on undulating band-like elements to troughs on adjacent band-like elements.
35. The stent of claim 34 wherein interconnecting elements extending from peaks of
- 15 a band-like element are separated from interconnecting elements extending from troughs of the band-like element by at least one unconnected peak having no interconnecting elements extending therefrom and at least one unconnected trough having no interconnecting elements extending therefrom.
36. The stent of any of claims 2-35, the plurality of undulating band-like elements
- 20 defining adjacent pairs of undulating band-like elements, adjacent pairs of undulating band-like elements having an undulating band-like element in common wherein the direction of the interconnecting elements reverses between adjacent pairs of interconnected undulating band-like elements.

Figure 11 shows a flat view of a stent configuration according to the invention.

Figure 12 shows a flat view of a stent configuration according to the invention.

5 Figure 13 shows the pattern of Figure 12 in a tubular stent.

Figure 14 shows an expanded stent of the configuration shown in Figure 12.

Figure 15 shows a flat view of an alternate stent configuration according to the invention.

10

#### Detailed Description of the Invention

While this invention may be embodied in many different forms, there are described in detail herein specific preferred embodiments of the invention. This description is an exemplification of the principles of the invention and is not intended to  
15 limit the invention to the particular embodiments illustrated.

For the sake of consistency, the terms 'peak' and 'trough' shall be defined with respect to the proximal and distal ends of the stent. Each of the stents has a proximal end 91 and a distal end 93 and a longitudinal axis 95, as seen in Fig. 1a. Peaks 36 are generally concave relative to the proximal end of the stent and generally convex  
20 relative to the distal end of the stent. Troughs 40, on the other hand, are generally convex relative to the proximal end of the stent and generally concave relative to the distal end of the stent. Notwithstanding this definition, the term peak is also intended to extend to regions 48 that are generally peak-like which may, nevertheless, contain trough-like regions within the peak-like region as seen in Fig. 1b. Similarly the term  
25 trough is also intended to extend to regions 52 that are generally trough-like which may, nevertheless, contain peak-like regions within the trough-like region as seen in Fig. 1b.

Corresponding to each peak 36 is an inner diameter peak 38 where the inner diameter of the band-like element reaches its peak. The set of points on a given band-like element which are distal to inner diameter peak 38 is denoted peak region 48.  
30 Similarly, corresponding to each trough 40 is an inner diameter trough 42 where the inner diameter of the band-like element reaches its trough. The set of points on a given band-like element which are proximal to inner diameter trough 42 is denoted trough region 52. For the sake of clarity, unless otherwise indicated, analogous portions of



stents will be similarly labeled, using three digit reference numerals to distinguish among the various embodiments shown.

Also included within this definition of peak regions and trough regions are peak regions which are comprised of multiple peaks as well as trough regions which are comprised of multiple troughs such as those shown schematically in Fig 1b. Peak 36 is seen to consist of two sub-peaks 36a,b and trough 40 is similarly seen to consist of two sub-troughs 40a,b. In the case of peaks containing sub-peak and troughs containing sub-troughs, the peak region 48 includes all of the points along the band-like element between the sub-peaks that make up the peak and similarly, the trough region 52 includes all of the points along the band-like element between the sub-troughs that make up the trough.

The inventive stents may incorporate one or more bands of a chosen wavelength. In some embodiments, the inventive stents include one or more small amplitude, short wavelength bands to provide for flexibility and one or more large amplitude, long wavelength bands to give side branch access or to provide for sections of alternative strengths such as soft and/or stiff sections.

Turning to the Figures, Figure 2 shows a flat view of a stent configuration and Figure 3 shows the stent of Figure 2 in tubular form. That is, the stent is shown for clarity in Figure 2 in the flat and may be made from a flat pattern 110 (Figure 2) which is formed into a tubular shape by rolling the pattern so as to bring edges 112 and 114 together (Figure 2). The edges may then be joined as by welding or the like to provide a cylindrical configuration such as that shown generally at 115 in Figure 3.

A more preferred method of manufacture begins with a thin walled tube which is then laser cut to provide the desired configuration. It may also be chemically etched or EDM'd (electrical discharge machined) to form an appropriate configuration.

The configuration can be seen in these Figures to be made up of one or more spaced first band-like elements 120. First band-like elements have a generally serpentine configuration to provide continuous waves to the first band-like elements. The waves are characterized by a plurality of peaks 124 and troughs 128 taking a generally longitudinal direction along the cylinder such that the waves in first band-like elements 120 open as the stent is expanded from an unexpanded state having a first diameter to an expanded state having a second diameter.

The stent further comprises a plurality of spaced second band-like elements 132 having a generally serpentine configuration to provide continuous waves to the second band-like elements. The waves are characterized by a plurality of peaks 136 and troughs 140 taking a generally longitudinal direction along the cylinder such that the waves in the second band-like elements open as the stent is expanded from an unexpanded state having a first diameter to an expanded state having a second diameter. First and second band-like elements are characterized by respective wavelengths and amplitudes with the wavelength and amplitude of the second band-like elements exceeding the wavelength and amplitude of the first band-like elements.

10 Adjacent first band-like elements 120 and second band-like elements 132 are interconnected via a plurality of interconnecting elements 144. The ends of interconnecting element are circumferentially offset from each other.

In an embodiment, as shown in Figs. 2 and 3, first band-like elements 120 and second band-like elements 132 alternate over the length of the stent.

15 Optionally, as shown in Figs. 2 and 3, each end 152 of the stent may terminate in a first band-like element. The invention also, however, contemplates each end terminating in a second band-like element, or further, one end terminating in a first band-like element and the other end terminating in a second band-like element.

While a minimum of one connecting element is required to join adjacent band-like elements, two or more interconnecting elements are preferred. In one embodiment, as shown in Figs. 2 and 3, adjacent first and second band-like elements 120 and 132 are connected with three interconnecting elements 144. Further, in one embodiment, adjacent interconnecting elements 144 extending from peaks 136 on a first band-like element 120 are spaced five peaks apart on the first band-like element while adjacent interconnecting elements 144 extending from troughs 140 on a second band-like element 132 are spaced three troughs apart on the second band-like element.

It is a further feature of the present invention that peaks 124 on first band-like elements 120 are circumferentially displaced on the periphery of the stent from troughs 140 on adjacent second band-like elements 132. It is desirable that peaks and troughs be displaced in the expanded state of the stent to minimize the possibility of pinching or overlap between adjacent band-like elements.

30 Although the stent of Fig. 2 is comprised of two different wavelength band-like elements, the invention contemplates stents with a plurality of different

wavelength band-like elements. As such, other stents may have three, four or more different wavelength band-like elements.

In another embodiment, the inventive stent is comprised of band-like elements of a single wavelength, interconnected by interconnecting elements. Turning  
5 to Figs. 4a and 4b, band-like elements 220a,b are interconnected by interconnecting elements 244a,b. Adjacent band-like elements 220a,b are 180° out of phase with one another. In the compressed state, the band-like elements consist of a plurality of peaks 236a,b and troughs 240a,b. Peak region 248a,b and trough region 252a,b have been shaded in one instance for illustrative purposes.

10 In the embodiment shown in Fig. 4a, each interconnecting element 244a extends between a peak region 248a and a trough region 252a. Rectilinear interconnecting elements 244a consist of a first shank 280a, a second shank 284a and a link 288a disposed in-between the first and second shanks 280a and 284a. First shank 280a extends in a longitudinal direction from peak region 248a and is substantially  
15 perpendicular to link 288a. Second shank 284a extends in a longitudinal direction from trough region 252a and is perpendicular to link 288a.

In the embodiment shown in Fig. 4b, the stent differs from the embodiment of Fig. 4a in that interconnecting element 244b extending between a peak region 248b and a trough region 252b is curvilinear rather than rectilinear.

20 In both figures 4a and 4b, the interconnecting elements are seen to emanate from the middle of the peak and trough regions.

In another embodiment, as shown in Fig. 5a, the inventive stent is comprised of band-like elements 320a of a single wavelength, interconnected by interconnecting elements 344a. Adjacent band-like elements 320a are 180° out of phase  
25 with one another. The band-like elements consist of a plurality of peaks 336a and troughs 340a. Interconnecting elements 344a extend between a peak region 348a and a trough region 352a. The peak regions 348a and trough regions 352a from which interconnecting elements 344a emanate on a given band-like element 320a are seen to extend longitudinally beyond adjacent peak regions 348a' and trough regions 352a' from  
30 which no interconnecting elements extend. The extension is such that at least a portion of peak regions 348a overlap longitudinally along the stent with at least a portion of

trough region 352a on an adjacent band-like element 320a'. Of course, the overlap is limited to the longitudinal direction and not to the circumferential direction.

In another embodiment, as shown in Fig. 5b, interconnecting elements 344b extend between peak region 348b and a second closest trough region 352b on an adjacent band-like element. Interconnecting elements 344b are seen to be perpendicular to the longitudinal axis. As in the stent of Fig. 5a, peak regions 348b from which interconnecting elements 344b extend and trough regions 352b from which interconnecting elements 344b extend may extend beyond adjacent peak regions 348b' and trough regions 352b' from which no interconnecting elements 344b emanates.

In another embodiment, as shown in Fig. 6, adjacent band-like elements 420 are in phase with each other. As in previous Figs, band-like elements 420 are of a single wavelength, interconnected by interconnecting elements 444. The band-like elements consist of a plurality of peaks 436 and troughs 440. Interconnecting elements 444 extend at an oblique angle relative to the longitudinal axis of the stent between a peak region 448 and a trough region 452. As such, ends of interconnecting elements 444 are circumferentially offset relative to each other. The exact angle will, of course, depend on the region from which the interconnecting elements extend, as well as on whether interconnecting elements interconnect nearest peaks and troughs, next nearest peaks and troughs or peaks and troughs that are further separated.

In Figures 5a, 5b and 6, the interconnecting elements are seen to emanate from the sides of the peak and trough regions.

Although for the embodiments of Figs. 1-6, the interconnecting elements extend from peak regions on band-like elements to trough regions on adjacent band-like elements, the invention further contemplates interconnecting elements extending from a position between a peak region and an adjacent trough region on a band-like element to a position intermediate a trough region and a peak region on an adjacent second band-like element as in Fig. 7.

In the embodiment of Fig. 7, interconnecting elements are seen to extend from a region between the peak region and the trough region on a band-like element. The stent is formed of adjacent band-like elements 520 which are 180° degrees out of phase with one another. Interconnecting elements 544 extend from a region intermediate a peak region 548 and a trough region 552 on a band-like element to a

region intermediate a peak region 548 and a trough region 552 on an adjacent band-like element. Interconnecting elements 544 consist of a first shank 560, a second shank 564, and an intermediate member 568 disposed in-between first and second shanks 560 and 564. First shank 560 and second shank 564 are substantially perpendicular to  
5 intermediate member 568 which extends in the longitudinal direction. Although not depicted, the region from which interconnecting elements 544 emanate may be midway between peaks and troughs.

The embodiment of Fig. 7 also differs from the embodiments of Figs. 2-6 in the orientation of the interconnecting elements. Whereas the interconnecting  
10 elements in Figs. 2-6 are all similarly oriented, in the embodiment of Fig. 7, the orientation of interconnecting elements alternates between adjacent pairs of adjacent band-like elements. Specifically, second shanks 564' of interconnecting elements 544' are seen to be displaced in a clockwise circumferential direction along the stent relative to first shanks 560', and second shank 564" of interconnecting elements 544" are seen  
15 to be displaced in a counterclockwise circumferential direction along the stent relative to while first shank 560".

This feature is also seen in the embodiment of Fig. 8 in which adjacent in-phase band-like elements 620 are interconnected by interconnecting elements 644. Interconnecting elements 644 extend at an oblique angle relative to the longitudinal axis  
20 of the stent between a peak region 648 and a trough region 652. As in Fig. 7, the orientation of interconnecting elements alternates between adjacent pairs of adjacent band-like elements. Specifically, the distal ends of interconnecting elements 644' are seen to be oriented in a counterclockwise circumferential direction along the stent relative to the proximal end of the interconnecting elements while the distal ends of  
25 interconnecting elements 644" are seen to be displaced in a clockwise circumferential direction along the stent relative to the proximal ends.

Although in the embodiments of Figs 2-8, adjacent bands are connected by five interconnecting elements, additional or fewer interconnecting elements may be used. Further, while interconnecting elements are shown spaced three peaks apart and  
30 three troughs apart, other separations are contemplated as well.

In the embodiment of Figure 9, each band-like element 720 is seen to comprise peaks 736 of more than one amplitude and troughs 740 of more than one

amplitude. Large amplitude peaks 736a and small amplitude peaks 736b alternate as do large amplitude troughs 740a and small amplitude troughs 740b. As in the previous embodiments, the interconnecting elements are oriented at an oblique angle relative to the longitudinal axis 795 of the stent. More generally, the invention is directed at stents comprising band-like elements whose amplitude varies along the band-like element.

In another embodiment of the invention, as shown in Fig. 10, each band-like element 820 is seen to comprise peaks 836 of more than one amplitude and troughs 840 of more than one amplitude, however, peaks of the same amplitude are grouped together within a band-like element as are troughs of the same amplitude. It is further noted that in the embodiment of Figure 10, the location of a group of peaks of given amplitude in a band-like element varies circumferentially along the length of the stent. Interconnecting elements 844 connect peaks 836 and troughs 840 in adjacent band-like elements 820. Where several peaks of different amplitudes are present in a band-like element, the invention further contemplates the possibility of interconnecting elements extending from the large peaks 836a to large troughs 840a as in Fig. 9 as well as the possibility of interconnecting elements extending from large peaks to small troughs or from small peaks 836b to large troughs 840a as in Fig. 10. Further, the interconnecting elements between any two adjacent band-like elements may be of different lengths from one another as seen in Fig. 10 and commence at different longitudinal positions within a band-like element and terminate at different longitudinal positions within a band-like element. Interconnecting element 844a is seen to be longer than interconnecting element 844b. As in the previous embodiments, the interconnecting elements are oriented at an oblique angle relative to the longitudinal axis 895 of the stent. In the embodiment of Fig. 10, interconnecting element 844a is seen to be oriented at a smaller oblique angle relative to the longitudinal axis of the stent than interconnecting element 844b. As is apparent from Fig. 10, the invention is also directed to stents comprised of band-like elements whose wavelength varies along a given band-like element. Region 898 and region 899 of band-like element are characterized by different wavelengths.

It is also noted that in the embodiment of Fig. 10, all of the troughs 840a,b in a given band-like element 820 are aligned longitudinally along the stent and differ only in their circumferential position along the stent.

It is further noted in the embodiment of Fig. 10, the stent comprises a first group of interconnecting elements 844a and a second group of interconnecting

elements 844b. The interconnecting elements of the first group are all parallel to one another and disposed at a different oblique angle relative to the longitudinal axis than the members of the second group which are all parallel to one another. As such, the invention contemplates stents having several different groups of obliquely disposed interconnecting elements where the oblique angle differs from group to group.

In another embodiment of the invention, as shown in Fig. 11, each band-like element 920 is seen to comprise peaks 936a,b of different amplitudes and troughs 940 of different amplitudes, however, peaks of the same amplitude are grouped together within a band-like element as are troughs of the same amplitude. It is further noted that in the embodiment of Figure 11 the location of groups of peaks of given amplitude in a band-like element varies circumferentially along the length of the stent. Interconnecting elements 944 connect large amplitude peaks 936a and small amplitude troughs 940b in adjacent band-like elements 920. Similarly, interconnecting elements 944 also connect small amplitude peaks 936b and large amplitude troughs 940a.

The invention also contemplates stents similar to that shown in Fig. 11 in which interconnecting elements extend from large peaks 936a to large troughs 940a, as in Fig. 9. Similarly, interconnecting elements may extend from small peaks 936b to small troughs 940b.

Further, the interconnecting elements between any two adjacent band-like elements may be of different lengths from one another and disposed at different oblique angles.

As is apparent from Fig. 11, the invention is also directed to stents comprised of band-like elements whose wavelength varies along a given band-like element. Region 998 and region 999 of band-like element 920 are characterized by different wavelengths.

It is also noted that in the embodiment of Fig. 11 the large amplitude portions 999 of band-like element 920 are symmetrically disposed about the center of the band-like element as are the small amplitude portions 998. The center of the band-like element is defined as a ring that runs along a path that is midway between the large peaks 936a and large troughs 940a of the band-like element. This feature may also be seen in the embodiment of Fig. 9.

The invention is also directed to a tubular, flexible, expandable stent having a longitudinal axis, comprising one or more cylindrical shaped first segments.

Cylindrical shaped first segments 20 as seen in Fig. 1, have first struts 23 having first 25 and second 27 ends. First segments 20 are defined by a member formed in an undulating pattern of interconnected paired first struts 23, in which adjacent pairs of first struts 29' and 29" in a given first segment 20 are interconnected at opposite ends 31' and 31", respectively. Adjacent segments are interconnected.

The stent may be seen more clearly in Figs. 2-8. As shown, the stent of Fig. 3, in addition to comprising first segments 120 which are defined by an undulating pattern of interconnected paired first struts 123 in which adjacent pairs of first struts 129' and 129" in a given first segment 120 are interconnected at opposite ends 131' and 131", respectively, the stent further comprises one or more cylindrical shaped second segments 132, each second segment being defined by a member formed in an undulating pattern of interconnected paired second struts 135 and in which adjacent pairs of second struts 137' and 137" in a given second segment 132 are interconnected at opposite ends 139' and 139", respectively. First struts 123 are shorter than second struts 135. First segments 120 are formed of a number of first struts 123 and second segments 132 formed of a number of second struts 135, the number of first struts in a first segment exceeding the number of second struts in a second segment. First and second segments 120 and 132 are aligned on a common longitudinal axis 195 to define a generally tubular stent body, shown generally at 115. First and second segments 120 and 132 alternate along the stent body. Adjacent first and second segments 120 and 132 are connected by a plurality of interconnecting elements 144. Each interconnecting element 144 extends from an end 131" of paired first struts on a first segment 120 to an end 139" of paired second struts on an adjacent second segment 132. The ends of interconnecting elements 144 are circumferentially offset relative to each other.

Desirably, upon expansion of stent 115, paired struts 129" and 137" of adjacent segments 120 and 132 are displaced relative to each other about the periphery of the stent body to accommodate longitudinal flexing of the stent within the segments and without interference between adjacent segments.

In the embodiments as shown in Figs. 4a, b, cylindrical shaped segments 220a,b are formed of interconnected struts 223a,b having first 225 and second 227 ends. Adjacent pairs of struts 229a,b' and 229a,b" in a given segment 220a,b are interconnected at opposite ends 231a,b' and 231a,b", respectively. Adjacent segments are connected by a plurality of interconnecting elements 244a,b. Each interconnecting



element 244a,b extends from an end of paired struts 231a,b" on a segment to an end of paired struts 231a,b' on an adjacent segment. First end 245a,b and second end 247a,b of interconnecting elements 244a,b are seen to be circumferentially displaced along the stent.

- 5                    Similar structure, denoted by similar reference numerals may be found in the stents of Figs. 5a,b, and 6-8.

                  In particular, in the embodiment as shown in Fig. 8, cylindrical shaped segments 620 are formed of interconnected struts 623, having first 625 and second 627 ends. Segments 620 are defined by a member formed in an undulating pattern of  
10   interconnected paired struts 623 in which adjacent pairs of struts 629' and 629" in a given segment 620 are interconnected at opposite ends 631' and 631", respectively. Segments 620 are aligned on a common longitudinal axis 695 to define a generally tubular stent body. Adjacent segments are connected by a plurality of interconnecting elements 644 (and 644') having first 645 (645') and second 647 (647') ends, each  
15   interconnecting element 644 (644') extending from an end of paired struts 631" on a segment to an end of paired struts 631' on an adjacent segment. First end 645 (645') and second end 647 (647") are seen to be circumferentially displaced along the stent.

                  Additional embodiment of the stents are shown in Figs 12-15. Figure 12 and Figure 13 show a fragmentary flat view of an unexpanded stent configuration  
20   and the actual tubular stent (unexpanded), respectively. That is, the stent is shown for clarity in Figure 12 in the flat and may be made from a flat pattern 1110 (Figure 12) which is formed into a tubular shape by rolling the pattern so as to bring edges 1112 and 1114 together (Figure 12). The edges may then joined as by welding or the like to provide a configuration such as that shown in Figure 13.

25                    The configuration can be seen in these Figures to be made up of a plurality of adjacent segments generally indicated at 1116, each of which is formed in an undulating flexible pattern of substantially parallel struts 1118. Pairs of struts are interconnected at alternating end portions 1119a and 1119b. As is seen in Figure 12, the interconnecting end portions 1119b of one segment are positioned opposite  
30   interconnecting end portions 1119a of adjacent segments. The end portions as shown are generally elliptical but may be rounded or square or pointed or the like. Any configuration of end portions is acceptable so long as it provides an undulating pattern, as shown. When the flat form 1110 is formed into an unexpanded tube as

shown in Figure 13, the segments are cylindrical but the end portions 1119 of adjacent segments remain in an opposed position relative to each other.

A more preferred method of manufacture begins with a thin walled tube which is then laser cut to provide the desired configuration. It may also be chemically etched or EDM'd (electrical discharge machined) to form an appropriate configuration.

Interconnecting elements 1120 extend from one end portion 1119 of one segment 1116 to another end portion 1119 of another adjacent segment 1116 but not to an oppositely positioned end portion 1119 of an adjacent segment 1116. There are at least three struts included between the points on each side of a segment 1116 at which an interconnecting element 1120 contacts an end portion 1119. This results in the interconnecting elements 1120 extending in an angular direction between segments around the periphery of the tubular stent. Interconnecting elements 1120 are preferably of the same length but may vary from one segment to the other. Also, the diagonal direction may reverse from one segment to another extending upwardly in one case and downwardly in another, although all connecting elements between any pair of segments are substantially parallel. Figure 12, for example shows them extending downwardly, right to left. Upwardly would extend up left to right in this configuration.

As a result of this angular extension of the interconnecting elements 1120 between adjacent segments and loops, upon expansion of the stent as seen in Figure 14, the closest adjacent end portions 1119 between segments 1116 are displaced from each other and are no longer opposite each other so as to minimize the possibility of binding or overlapping between segments, i.e., pinching.

The number of interconnecting elements 1120 may vary depending on circumstances in any particular instance. Three per segment are satisfactory for the configuration shown and at least three will be used typically.

The alternate design shown in Figure 15 includes longer struts 1118a in the two end segments 1116a than in the intermediate segments 1116. This allows the end-segments (1116a) to have less compression resistance than the intermediate segments (1116), providing a more gradual transition from the native vessel to the

support structure of the stent. Otherwise, the configuration is the same as that shown in Figure 12.

As indicated in the Figures, the invention contemplates a variation of interconnecting element shapes ranging from rectilinear to curvilinear. The invention further contemplates embodiments in which all interconnecting elements are similarly oriented as well as embodiments in which adjacent sets of interconnecting elements extending between adjacent pairs of segments are oppositely oriented (e.g., Figs 7 and 8). The invention also contemplates the use of interconnecting elements which extend from a range of positions along the segments, ranging from various positions in the area in which paired struts are interconnected to other positions along the struts.

The invention also contemplates the possibility of interconnecting elements extending at an oblique angle relative to the longitudinal axis of the stent and connecting adjacent peaks and troughs on adjacent segments as well as peaks and troughs on adjacent segments which are separated by one or more peaks and/or troughs.

The invention also contemplates reversing the orientation of interconnecting elements as shown in Figs. 7 and 8.

Finally, there are preferably at least three interconnecting elements joining adjacent first and second segments although fewer or additional interconnecting elements are also contemplated.

It is understood that the peaks and troughs of the present invention need not be rounded, as shown in the Figures. The peaks and troughs may be bulbous, triangular, square, pointed, or otherwise formed of interconnected straight sections.

As already indicated, this invention is applicable to self-expanding configurations, mechanically expandable configurations and to a wide variety of materials, including both metal and plastic and any other material capable of functioning as an expandable stent. For example, the stent may be of metal wire or ribbon such as tantalum, stainless steel or the like. It may be thin-walled. It may be of shape memory alloy such as Nitinol or the like, etc. The interconnecting elements may be formed integrally with the band-like elements (or segments) or may be bonded thereto via such methods as adhesive bonding, welding or any other known method of bonding.

The above Examples and disclosure are intended to be illustrative and not exhaustive. These examples and this description will suggest many variations and alternatives to one of ordinary skill in this art. All these alternatives and variations are

intended to be included within the scope of the attached claims. Those familiar with the art may recognize other equivalents to the specific embodiments described herein which equivalents are also intended to be encompassed by the claims attached hereto.

What is claimed is as follows:

1. A cylindrical expandable stent comprising:  
a plurality of undulating band-like elements, the band-like elements having  
alternating peaks and troughs, aligned on a common longitudinal axis to define a  
5 generally tubular stent body, the peaks and troughs taking a generally longitudinal  
direction along the cylinder, and  
a plurality of interconnecting elements each interconnecting element having a  
first end and a second end, the first and second ends extending from adjacent band-like  
elements, the first and second ends displaced circumferentially along the stent.
- 10 2. The stent of claim 1, wherein the band-like elements comprise first and second  
band-like elements, the first band-like elements having a first selected wavelength, the  
second band-like elements having a second selected wavelength, the second selected  
wavelength longer than the first wavelength.
3. The stent of claim 2 wherein the first and second band-like elements alternate  
15 over the length of the stent and each interconnecting element extends from a first band-  
like element to a second band-like element.
4. The stent of claim 3 wherein adjacent first and second band-like elements are  
connected with two or more interconnecting elements.
5. The stent of claim 3 wherein the first band-like elements are characterized by a  
20 first amplitude and the second band-like elements are characterized by a second  
amplitude, the second amplitude greater than the first amplitude.
6. The stent of claim 3 wherein adjacent interconnecting elements extending from  
peaks on a first band-like element are spaced five peaks apart on the first band-like  
element.
- 25 7. The stent of claim 3 wherein adjacent interconnecting elements extending from a  
trough on a second band-like element are spaced three troughs apart on the second band-  
like element.
8. The stent of claim 3 wherein the peaks on the first band-like elements are  
circumferentially displaced on the periphery of the stent from the troughs on adjacent  
30 second band-like elements.
9. The stent of claim 2 wherein interconnecting elements extend from peaks on first  
band-like elements to troughs on adjacent second band-like elements and from peaks on  
second band-like elements to troughs on adjacent first band-like elements.

10. The stent of claim 1 wherein each interconnecting element extends from a position intermediate a peak and an adjacent trough on a first band-like element to a position intermediate a trough and an adjacent peak on a second band-like element.
11. The stent of claim 1 wherein adjacent band-like elements are about 180° out of  
5 phase with one another.
12. The stent of claim 1 wherein each of the interconnecting elements consists of a first shank, a second shank and a link disposed in-between the first and second shanks, the first shank extending in a longitudinal direction from the peak, the link substantially perpendicular to the first shank, and the second shank extending in a longitudinal  
10 direction from the trough and perpendicular to the link.
13. The stent of claim 1 wherein the interconnecting member is substantially perpendicular to the longitudinal axis of the stent.
14. The stent of claim 1 wherein each peak is connected with a second nearest trough on an adjacent band-like element.
15. 15. The stent of claim 1 wherein adjacent band-like elements are about 90° out of phase with one another.
16. The stent of claim 1 wherein the interconnecting elements extend between a peak and a second closest trough on an adjacent band-like element.
17. The stent of claim 1 wherein adjacent band-like elements are connected with five  
20 interconnecting elements.
18. The stent of claim 1 wherein adjacent interconnecting elements extending from peaks on a first band-like element are spaced three peaks apart on the band-like elements.
19. The stent of claim 1 wherein the interconnecting elements are rectilinear.
- 25 20. The stent of claim 19 wherein the interconnecting elements are straight.
21. The stent of claim 1 wherein the interconnecting elements include a portion which is curvilinear.
22. The stent of claim 1 wherein all of the band-like elements are of the same wavelength.
- 30 23. The stent of claim 1 wherein the first and second ends of each interconnecting element are displaced longitudinally along the stent.

24. The stent of claim 1, the band-like elements comprising first and second band-like elements, the first band-like elements having more peaks than the second band-like elements.

25. A tubular, flexible, expandable stent having a longitudinal axis, comprising:

5                   one or more cylindrical shaped first segments, each first segment having first struts having first and second ends, the first segment being defined by a member formed in an undulating pattern of interconnected paired first struts and in which adjacent pairs of first struts in a given first segment are interconnected at opposite ends,

                  one or more cylindrical shaped second segments, each second segment  
10   being defined by a member formed in an undulating pattern of interconnected paired second struts and in which adjacent pairs of second struts in a given second segment are interconnected at opposite ends,

                  the first struts being shorter than the second struts,

                  the first segments formed of a number of first struts and the second  
15   segments formed of a number of second struts, the number of first struts in a first segment exceeding the number of second struts in a second segment.

                  the first and second segments aligned on a common longitudinal axis to define a generally tubular stent body, the first and second segments present along the stent body, and

20                   adjacent first and second segments connected by a plurality of interconnecting elements, each interconnecting element having a first end and a second end, each interconnecting element extending from an end of paired first struts on a first segment to an end of paired second struts on an adjacent second segment, each first end of an interconnecting element displaced circumferentially along the stent from each  
25   second end of an interconnecting element.

26. The stent of claim 25 where each first end of an interconnecting element is longitudinally displaced from each second end of an interconnecting element.

27. The stent of claim 25 where there are at least three interconnecting elements joining adjacent first and second segments.

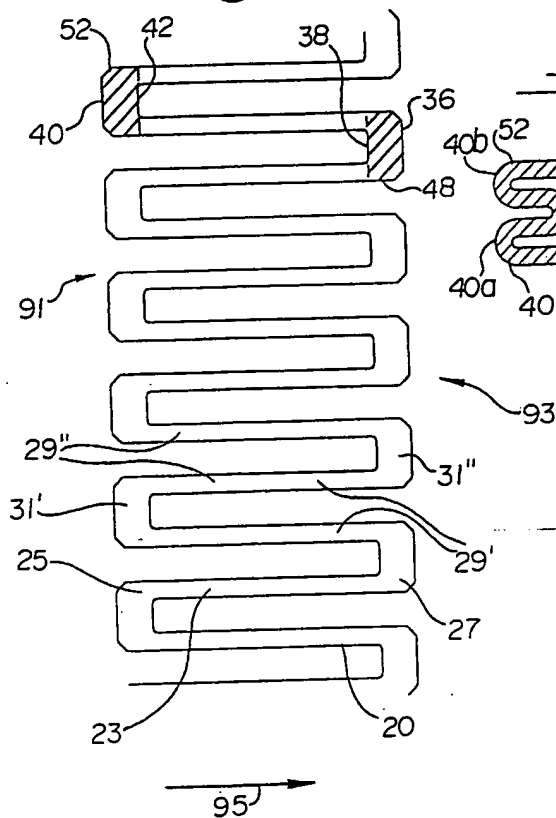
30   28. The stent of claim 25 where adjacent interconnecting elements are separated by five pairs of first struts on the first segments and three pairs of second struts on the second segments.

29. The stent of claim 1 formed of a metal.

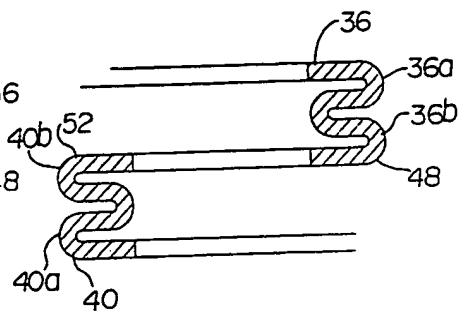
30. The stent of claim 29 wherein the metal is a shape memory alloy.
31. The stent of claim 1 wherein the stent is a thin-walled tubular member.
32. The stent of claim 1 in a self-expanding configuration.
33. The stent of claim 1 in a mechanically expandable configuration.
- 5 34. The stent of claim 1 comprising interconnecting elements of a plurality of different lengths.
35. The stent of claim 34 wherein adjacent band-like elements are interconnected by interconnecting elements of more than one length.
36. The stent of claim 1 comprising band-like elements whose wavelength varies  
10 along the band-like element.
37. The stent of claim 1 comprising band-like elements whose amplitude varies along the band-like element.



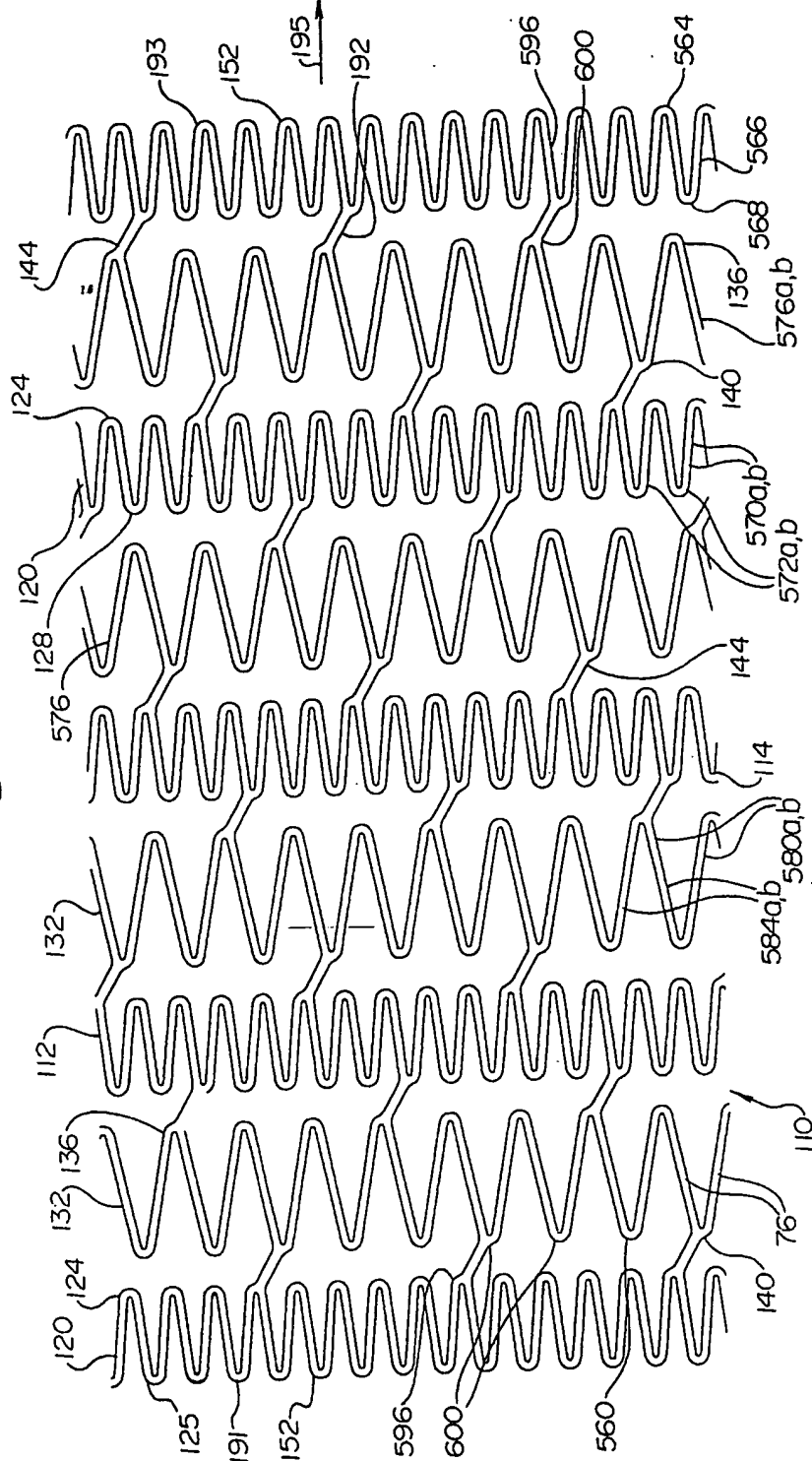
**Fig. 1a**



**Fig. 1b**

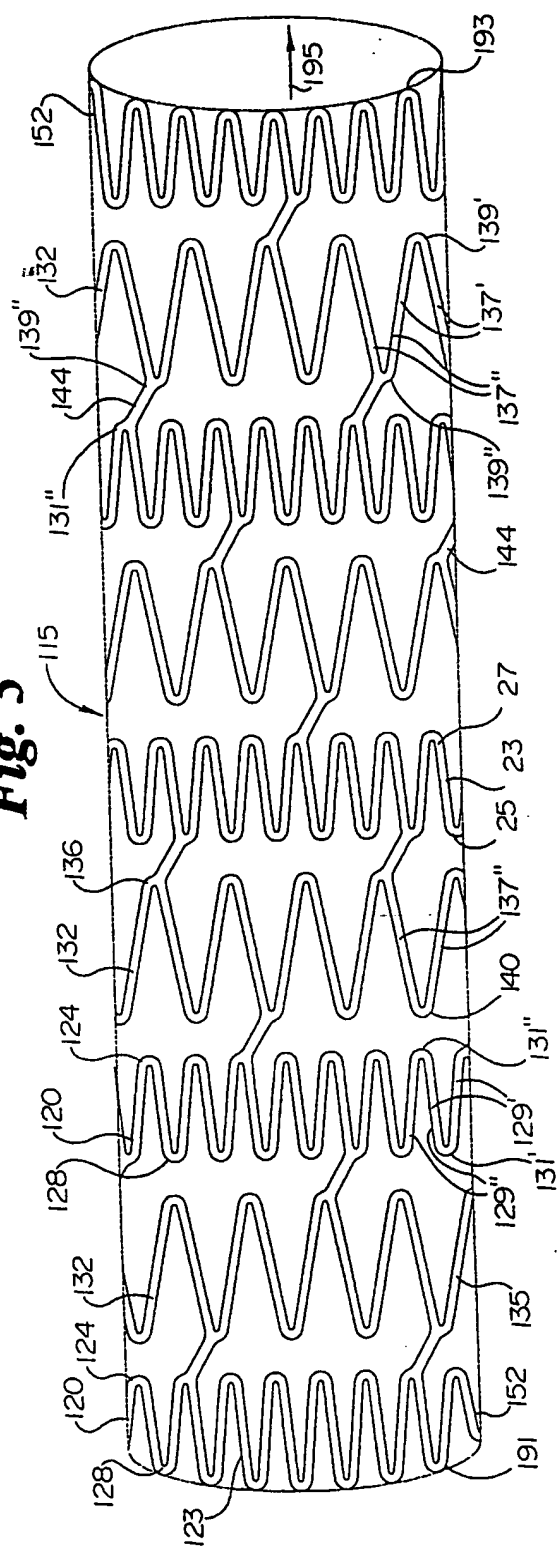


**Fig. 2**

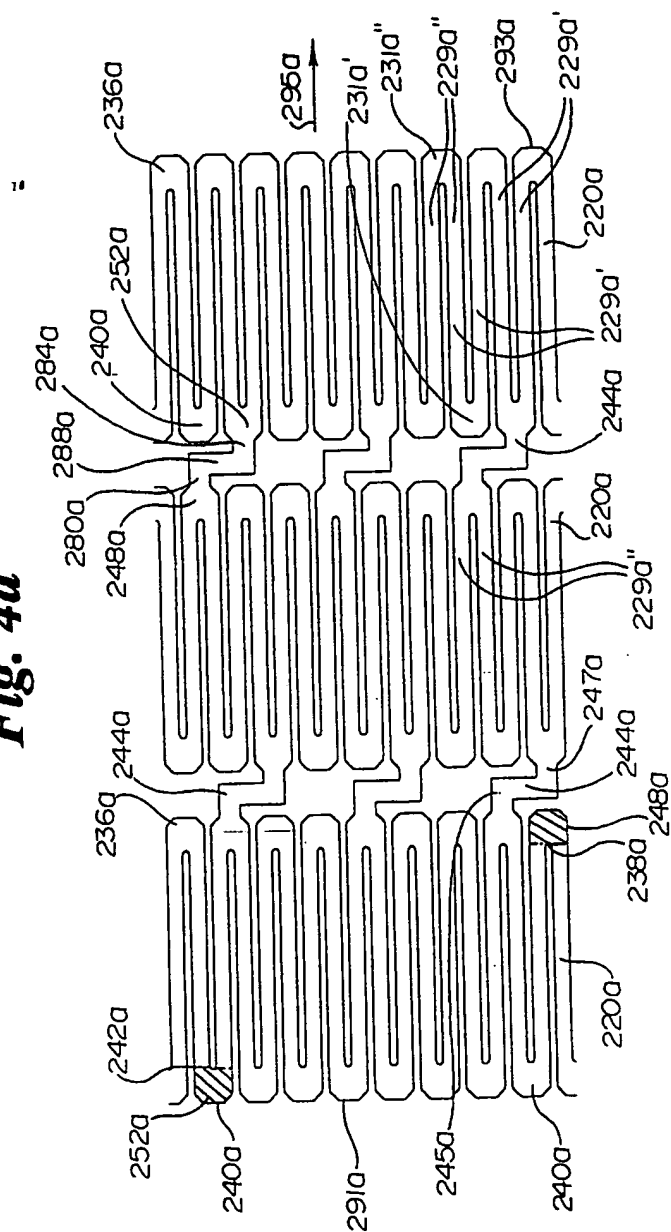


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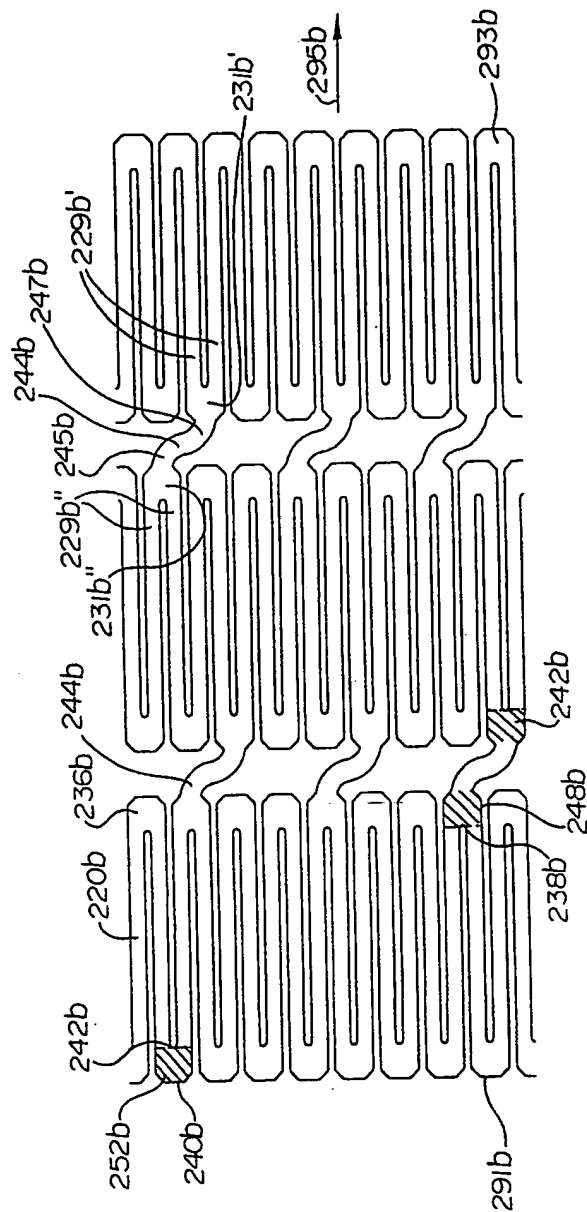
**Fig. 3**



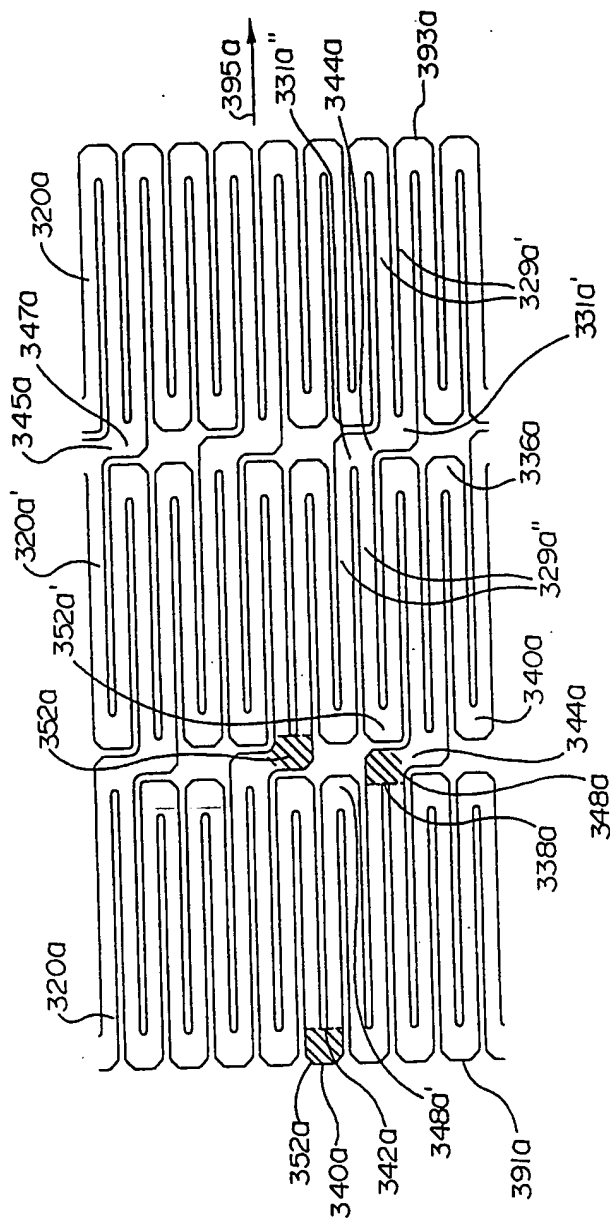
**Fig. 4a**



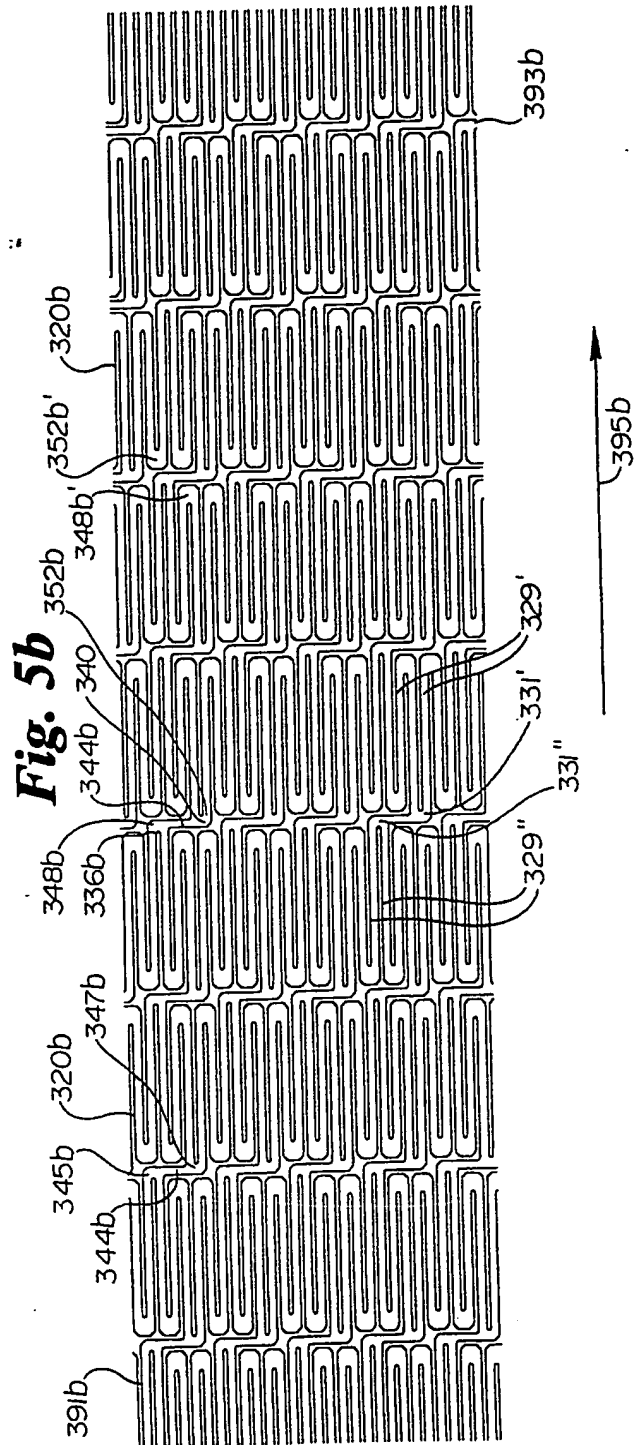
**Fig. 4b**



**Fig. 5a**

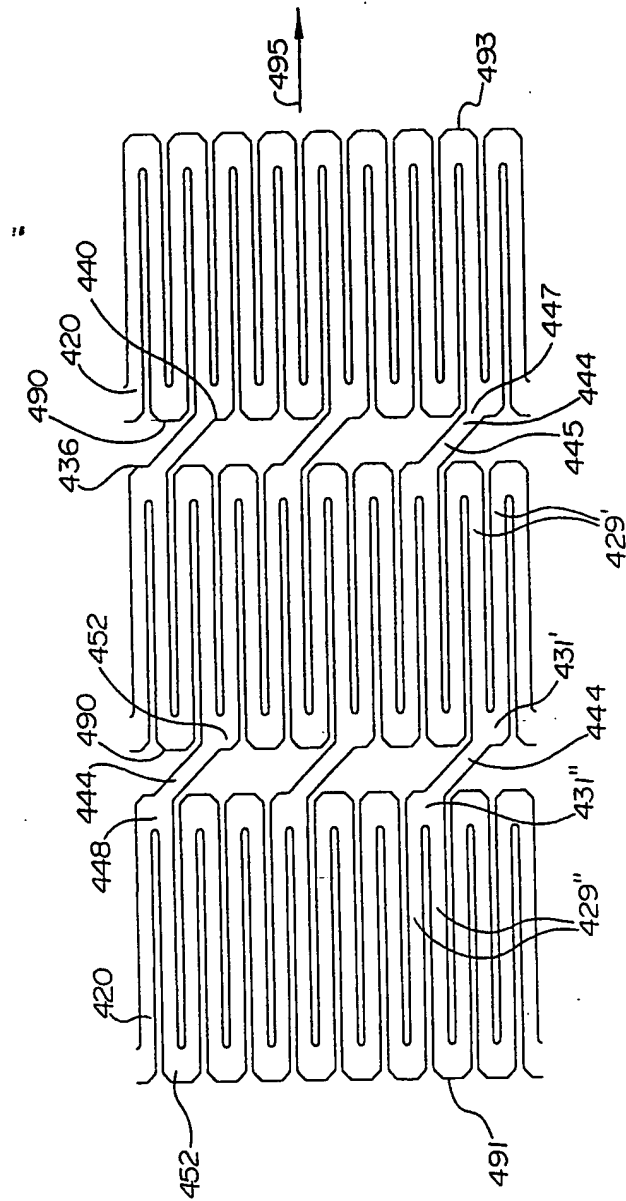


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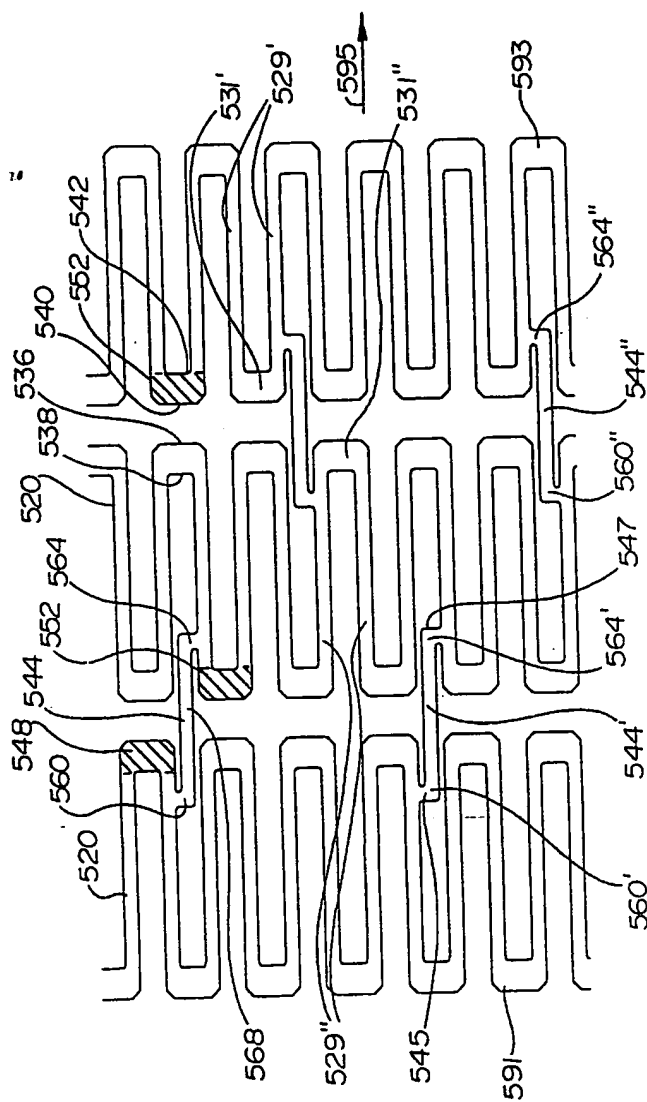
**Fig. 6**





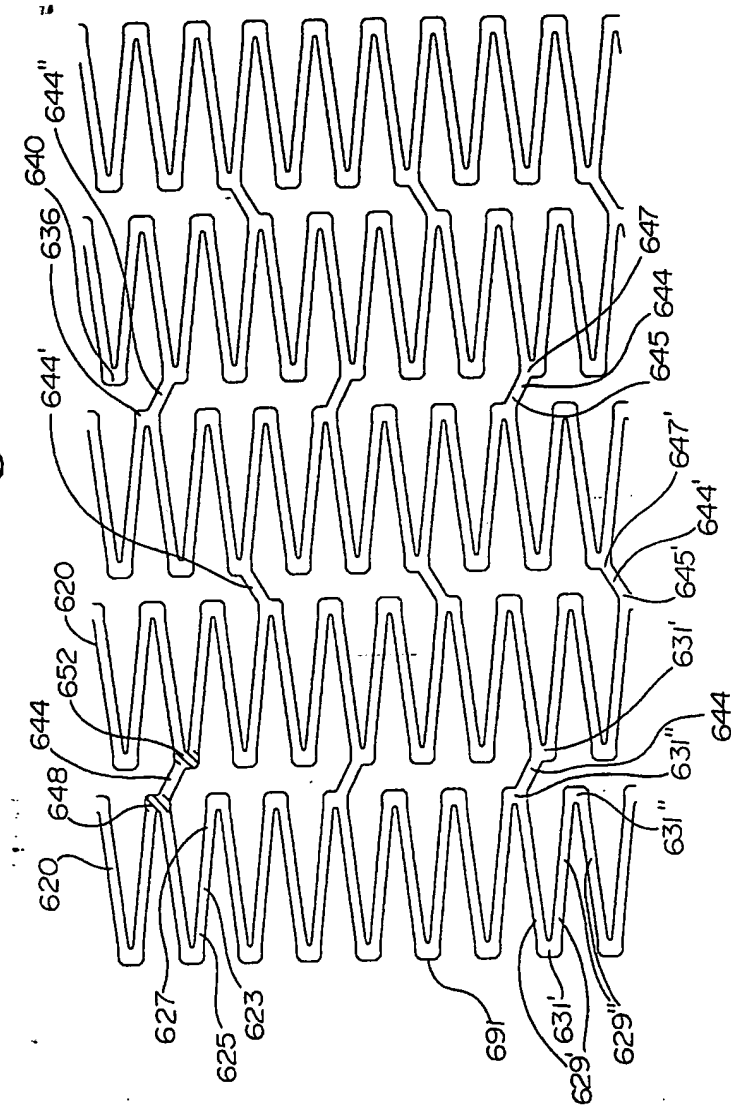
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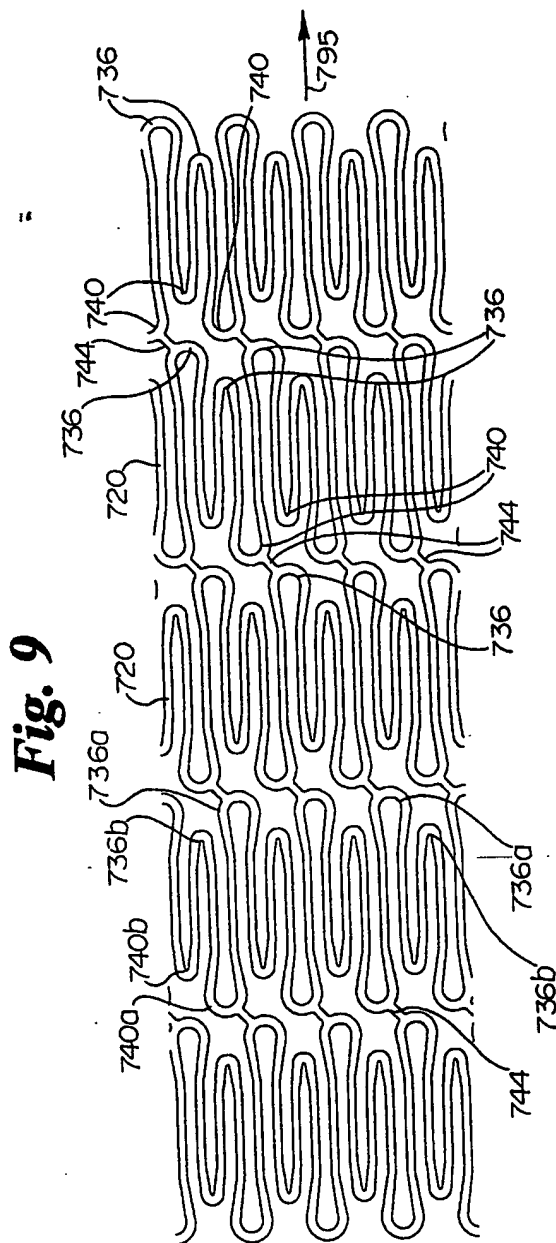
**Fig. 7**



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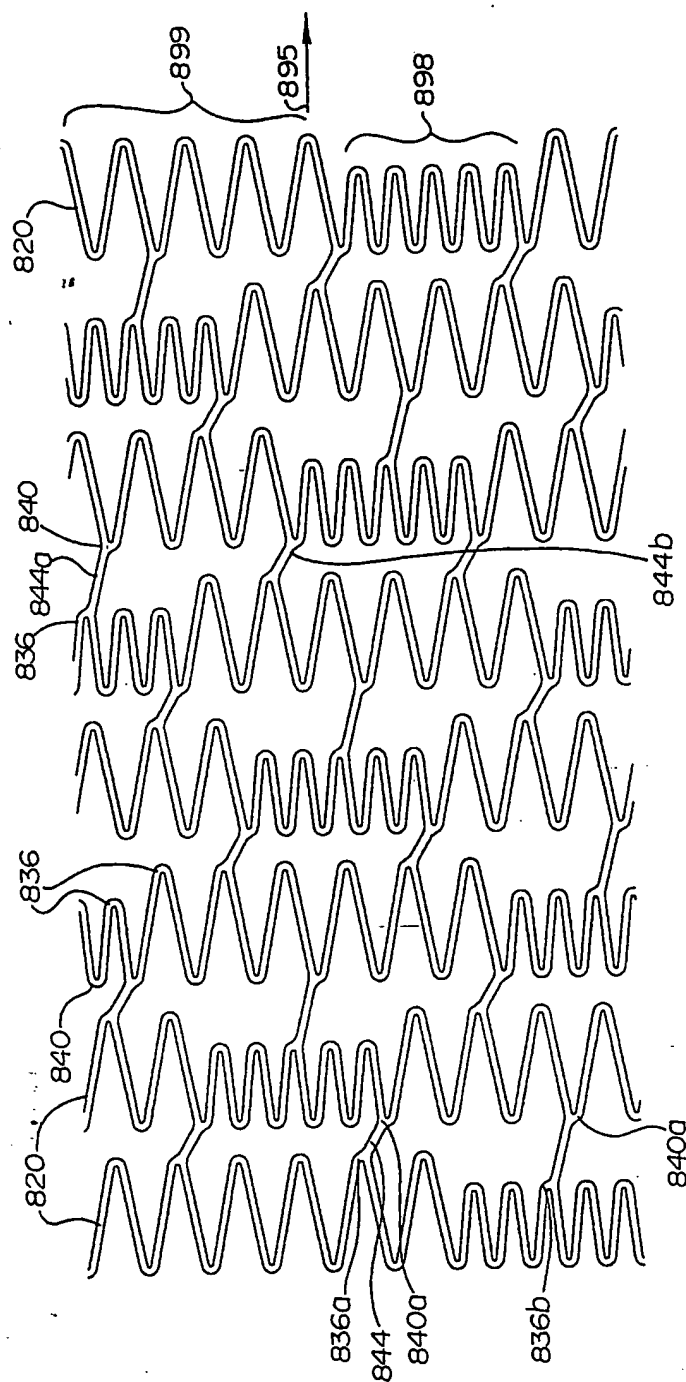
**Fig. 8**



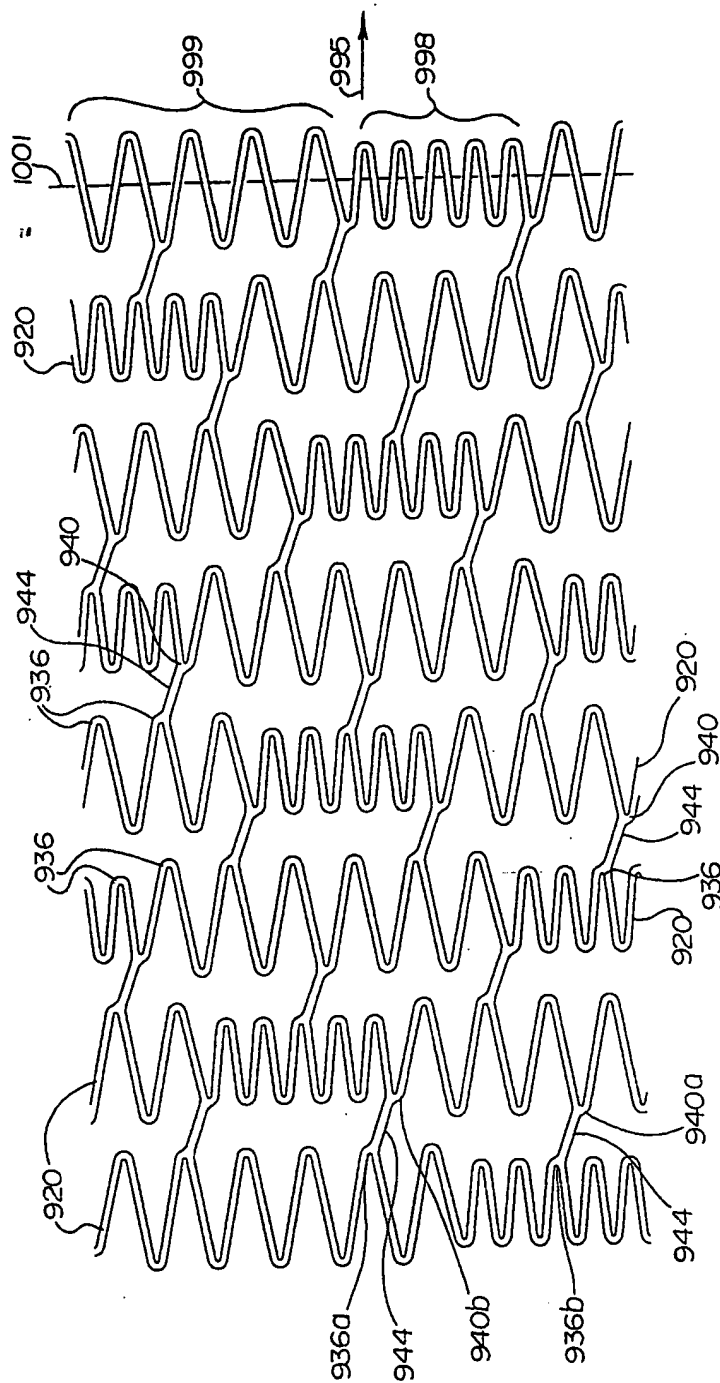


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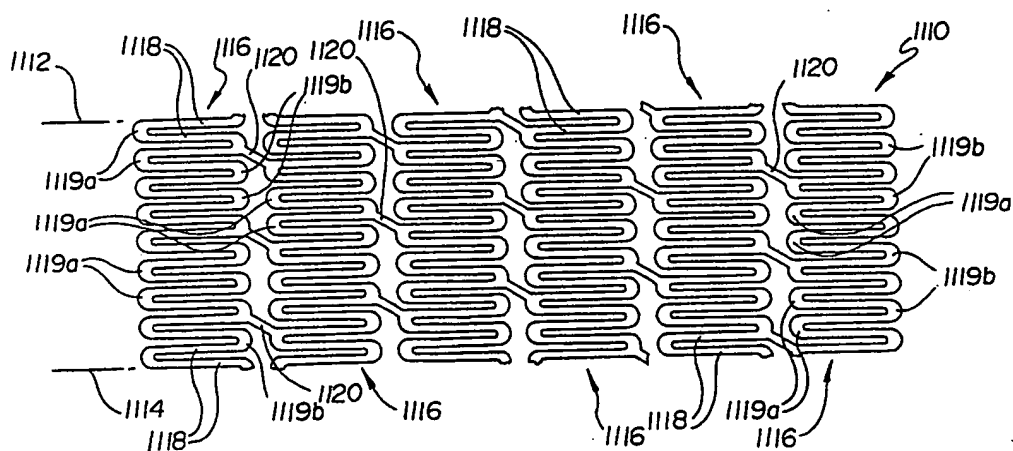
**Fig. 10**



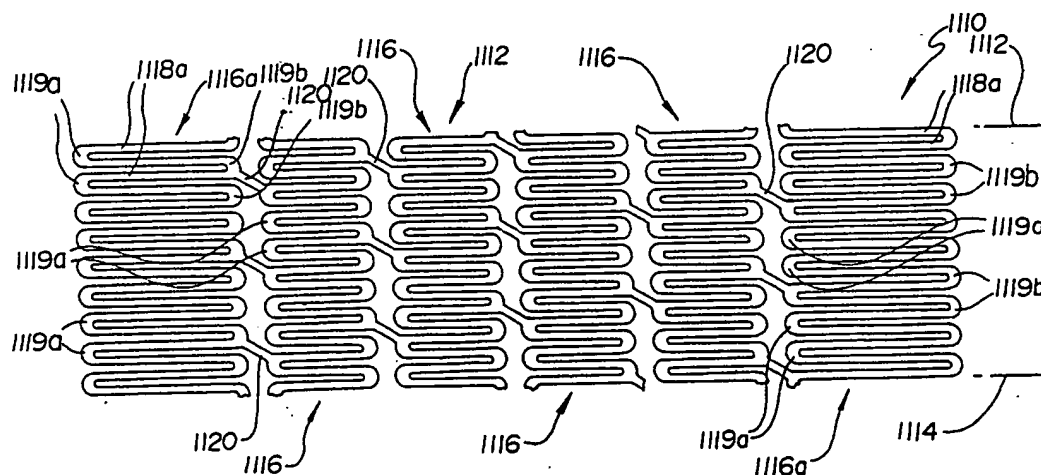
**Fig. 11**



**Fig. 12**



**Fig. 15**



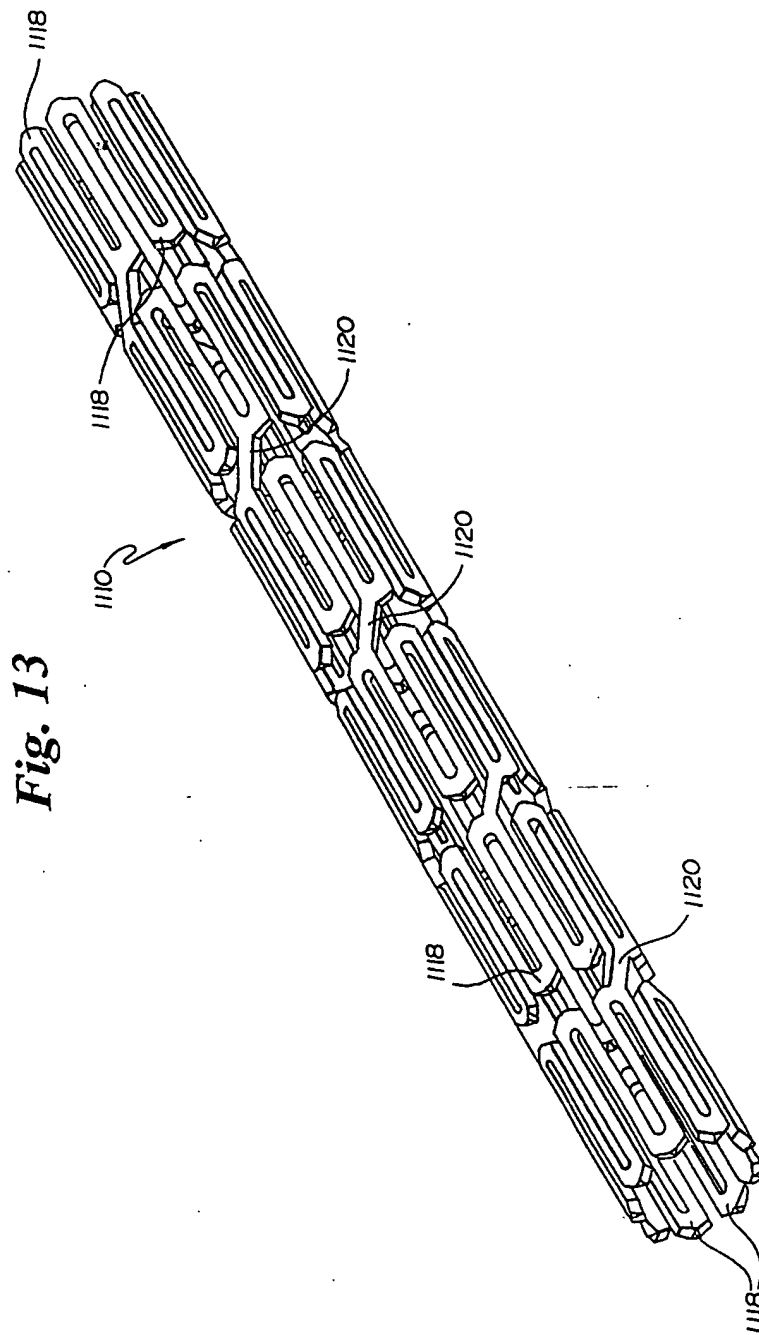
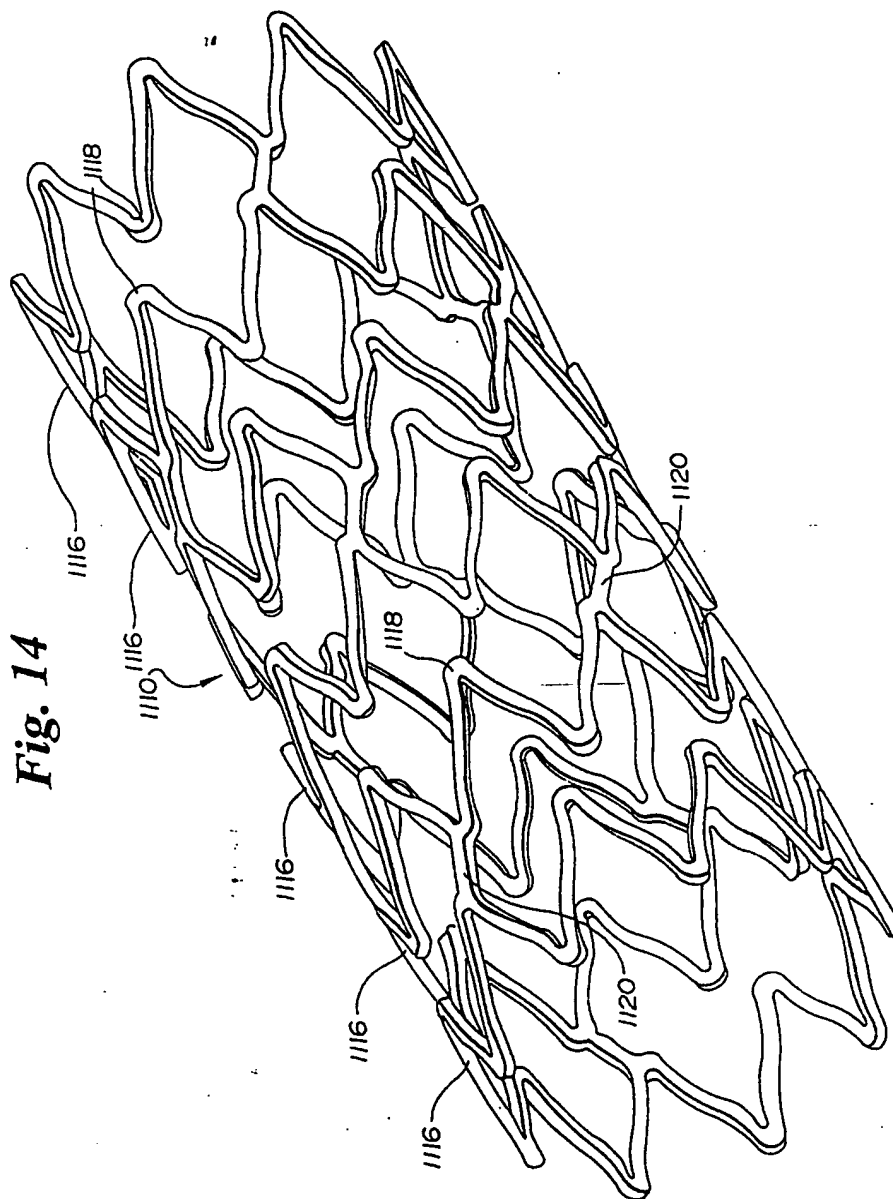


Fig. 13



**Fig. 14**



# INTERNATIONAL SEARCH REPORT

International Application No  
PCT/US 99/22161

## A. CLASSIFICATION OF SUBJECT MATTER

IPC 7 A61F2/06

According to International Patent Classification (IPC) or to both national classification and IPC

## B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)  
IPC 7 A61F

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practical, search terms used)

## C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category *	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	WO 96 26689 A (SCIMED LIFE SYSTEMS, INC.) 6 September 1996 (1996-09-06)  the whole document	1,2,11, 17-20, 22,23, 25-27, 29-33
X	WO 98 20810 A (MEDTRONIC, INC.) 22 May 1998 (1998-05-22)  the whole document	1,11-13, 15,17, 19-23, 29-31,33 10,32 25
Y	DE 297 16 476 U (CONVENT) 18 December 1997 (1997-12-18) figures 2,3	10,32
A		
Y		
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☒ Further documents are listed in the continuation of box C.

☒ Patent family members are listed in annex.

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Date of the actual completion of the international search

16 March 2000

Date of mailing of the international search report

23/03/2000

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# INTERNATIONAL SEARCH REPORT

International Application No.  
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## C. (Continuation) DOCUMENTS CONSIDERED TO BE RELEVANT

Category *	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	EP 0 876 806 A (SABARIA) 11 November 1998 (1998-11-11) the whole document	1, 21-23, 29-31, 33

# INTERNATIONAL SEARCH REPORT

Information on patent family members

Inter. natl Application No

PCT/US 99/22161

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WO 9820810 A	22-05-1998	NONE	
DE 29716476 U	18-12-1997	DE 29805761 U	06-08-1998
EP 876806 A	11-11-1998	FR 2762777 A	06-11-1998